Industrial Engineering Letters
ISSN 2224-6096 (Paper) ISSN 2225-0581 (online)
Vol.3, No.12, 2013
www.iiste.org

Evaluation of performance of locally fabricated Picnic coolers

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Abstract

Picnic coolers are locally fabricated refrigerators for picnic and other outdoor events using principle of vapour compression cycle. Evaluation of their Performances is necessary to be compared with other domestic refrigerators. The performance of the refrigeration system in term of Refrigeration Capacity, Coefficient of Performance (COP) and refrigerating efficiency were determined for four different picnic coolers of the same designed with 1/8 hp compressors. The average maximum actual coefficient of Performance of the Picnic coolers was about 0.98 and refrigeration capacity was around 86 watt. The environmental temperature also affected the performances of the refrigerators.

KEYWORD: Refrigeration; Capacity; Coefficient; efficiency

1.0 Introduction

Picnic coolers are locally fabricated refrigerator which movable to refrigerate drinks during picnic and outdoor events. They designed and constructed with normal blow-molded plastic, thermal insulated picnic box as the cabinet with evaporator for cooling. They have condensers, compressors, dryers and capillary tubes with thermostats for temperature control using the principle of vapour compression refrigeration cycle as shown in figure 1. The components designed and sized to suit refrigerant R-12 which has been widely used for many years. The refrigerant possesses desirable physical and thermodynamic properties and can be employed in a wide range of applications and temperatures with good system performance. It is also safe in terms of toxicity and flammability. Its Refrigeration capacity can employ smaller compressors (Hwang et al, 2005). Many research works have been done on R12. It has been reported that the power consumption of a R12 system would be 10 - 15% less than an R134a system (Devotta et al, 2005). The experimental and numerical analysis were carried out on a top-mount refrigerator and COP is within 1.25 and 1.05 (Barbosa et al, 2010).The performance study on a single evaporator domestic refrigerator indicated that the COP of R12 is 3% more than that of R13a (Muir, 1995, Jung and Radermacher, 1991). Experimental studies on the retrofitted R134a system indicated 5 - 8% lesser COP than that of a conventional R12 system (Camporese et al, 1997). The COP of system decreases with the decreases of evaporating temperature. The COP at 25°C is slightly higher than that at 28°C for all refrigerants. This is due to the fact that the compressor efficiency decreases with the increase of ambient temperature which ultimately affects the coefficient of performance (Saidur et al, 2000). There are four picnics cooler sets of experiment data were collected in order to evaluate the COP of the refrigerator. Each data was collected for a cycle of operation in about 3 hours. The result shows that the average COP of the refrigeration system using the refrigerator test rig was about 2.7. The result shows that the average COP of the refrigeration system using the refrigerator test rig was about 2.7. (Taib et al, 2010). The capital cost per unit of the refrigerator is about # 15000 (about $ 100).

Nomenclature

COP_a	Actual Coefficient of Performance (-)
COP_{th}	Theoretical Coefficient of performance (-)
Q	Refrigeration capacity (W)
t	Time (s)
P	Pressure (N m^{-2})
V_a	volume by the air (m^3)
V_w	volume of the water (m^3)
V	volume by the cabinet

M_a mass of air (Kg)
Cp_w the heat capacity of water (KJ Kg^{-1} $^OC^{-1}$)
T the measured temperature (^OC)
T_a atmosphere temperature (^OC)
W the work input by the compressor (W)
Cp_a the heat capacity of air (KJ Kg^{-1} $^OC^{-1}$)
ΔT difference between the initial temperature of the water and the measured temperature at time interval. (^OC)
R specific gas constant of the air (KJ kg^{-1} K^{-1})
W_c the work input by the compressor (W).
η Refrigerating efficiency (-)

2. Theory

Refrigeration capacity is the quantity of heat absorbed system in order to provide necessary cooling effect on the products inside the cabinet.

$$Q = (1000xV_wxCp_w + M_a x Cp_a) x \Delta T \quad (1)$$

While the mass of the air within the cabinet,

$$M_a = \frac{PV_a}{RT} \quad (2)$$

Moreover, the actual Coefficient of Performance is the ratio of refrigeration capacity to work input by the compressor.

$$COP_a = \frac{Q}{W_c} \quad (3)$$

and the theoretical Coefficient of performance is ratio of the measured temperature to the difference between atmosphere temperature and the measured temperature.

$$COP_{th} = \frac{T}{T_a - T} \quad (4)$$

Then, Refrigerating efficiency, the ratio of actual coefficient of performance and theoretical coefficient of performance will be,

$$\eta = \frac{COP_a}{COP_{th}} \quad (5)$$

3. Methodology

Experiments were carried out on four fabricated refrigerated picnic coolers of 1/8 HP compressors and the cooling cabinets are 0.43 X 0.15 X 0.15 meters. The atmosphere temperature was 32^{o}C. The heat capacities of water and air were taken to be 4.186 KJ Kg^{-1} $^OC^{-1}$ and 1.012 KJ Kg^{-1} $^OC^{-1}$ respectively. The atmospheric pressure was taken to be 1.03bar and the specific gas constant of the air, 287.058 J kg^{-1} K^{-1}. The refrigerators were run for 3 hours and the temperatures inside the coolers were taken at 30 minutes interval with 75cl bottles filled with water inside the cabinets. The volume of air is taken to be different between the volumes of the cabinet and that

of the bottle in the each cabinet. These experiments were taken for 7 days. The average temperatures for each refrigerator were calculated as shown in Tables 1-4 and averaged values for the four refrigerators were calculated as shown in Table 5

4. Result and Discussion

There are three important parameters that were recorded which are temperatures of the water in the 75 cl bottles and atmosphere temperature. The data were analyzed according to the theory of refrigeration system and the results are tabulated in table 2 to table 4 and table 5 represents the averaged data of the four refrigerators.

4.1 Refrigeration Capacity

Refrigeration capacity is determined using equation 1. Figure 2 shows graph of the variation of the refrigeration capacity with time for the all data. The graph shows a general trend at the first 1500 to 2500 seconds operation. In the period of time the refrigeration capacity is significantly high and then decreases.

4.2 Coefficient of Performance

Actual Coefficient of performance was calculated using equation 3 and figure 3 shows the graph of its variation with time. Referring to the figure, the values were higher at the beginning of each test run, and then achieved steady state condition after 2500 seconds of running.

4.3 Refrigerating efficiency

It was calculated using equation 5 and figure 4 shows the graph of the variation of refrigerating efficiency with time. Referring to the figure, the refrigerating efficiency values increased as the time increased.

5. Conclusion

The Picnic coolers were constructed by different people and of different colour. The amount of heat leakages in coolers would not be same. The averaged maximum actual coefficient of Performance of the Picnic coolers is about 0.98 and refrigeration capacity is around 86 watt. The refrigeration capacity and actual coefficient of performance reduced as the time increased but the refrigerating efficiency increased as the time increased. This shows that environmental temperature affect the performance of the refrigerators. Since the constant environmental temperature was used. The differences between the temperatures inside the cabinets and outside were increasing and the theoretical coefficient of performance reducing which made the refrigerating efficiency increasing. The COP of these refrigerators is lower than all cited COP in the paper.

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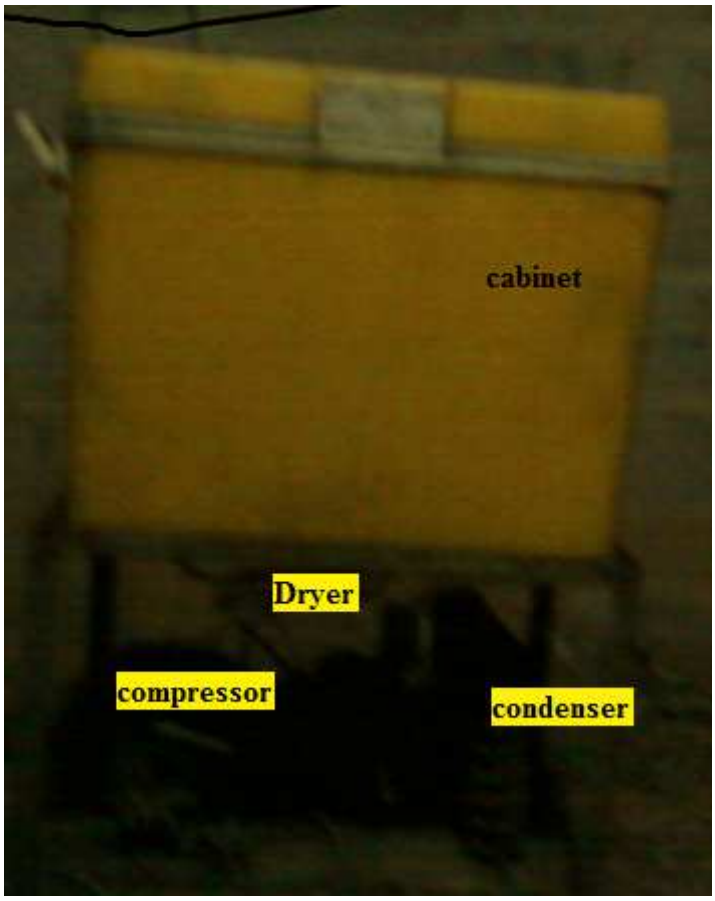

Fig. 1: Fabricated Picnic Refrigerator

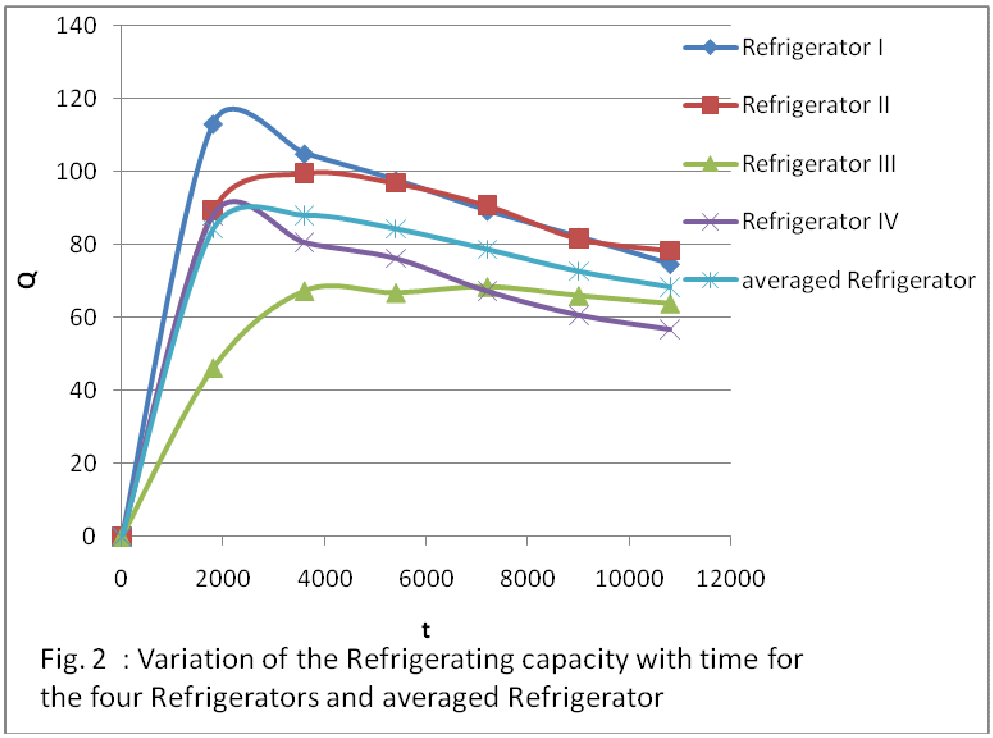

Fig. 2 : Variation of the Refrigerating capacity with time for the four Refrigerators and averaged Refrigerator

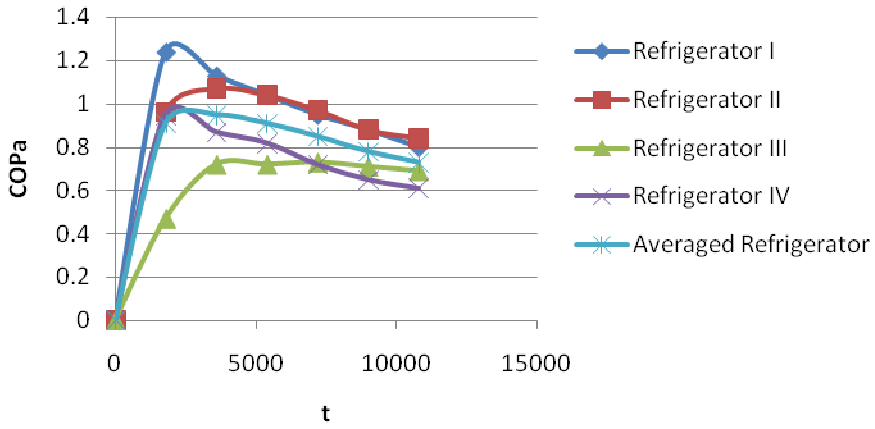

Fig. 3 : Variation of the Actual Coefficient of performaces with time for the four Refrigerators and averaged Refrigerator

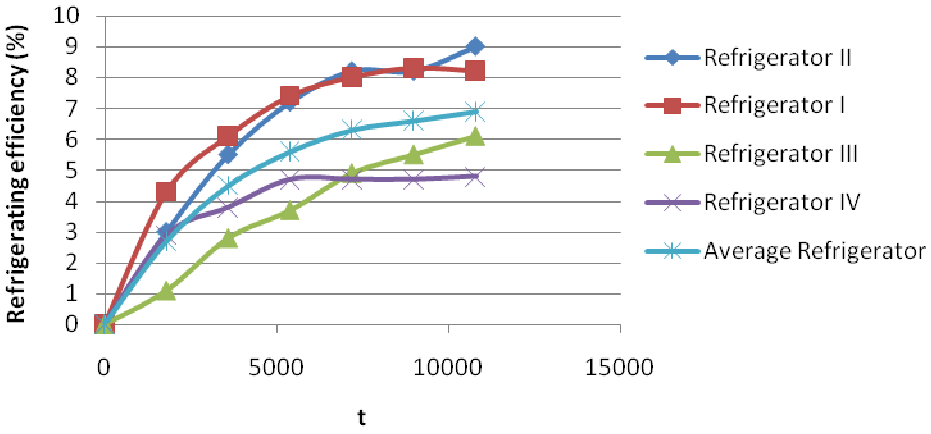

Fig. 4 : Variation of the Refrigerating efficiency with time for the four Refrigerators and averaged Refrigerator

Table 1 – The data from refrigerator I

t	T	Q	COP_a	COP_{th}	ɳ
0	0	0	0	0	**0**
1800	21.8	113.1	1.24	28.27	**4.3**
3600	16.7	104.94	1.13	18.58	**6.1**
5400	12.3	97.66	1.04	14.25	**7.4**
7200	8.9	89.29	0.95	12.02	**8.0**
9000	6.0	82.16	0.88	10.61	**8.3**
10800	4.0	74.72	0.80	9.79	**8.2**

Table 2 – The data from refrigerator II

t	T	Q	COP_a	COP_{th}	η
0	0	0	0	0	0
1800	23.1	89.28	0.96	32.33	3.0
3600	17.3	99.50	1.07	19.33	5.5
5400	12.4	96.78	1.04	14.35	7.2
7200	8.6	90.65	0.97	11.87	8.2
9000	6.1	81.62	0.88	10.67	8.2
10800	2.9	78.31	0.84	9.37	9.0

Table 3 – The data from refrigerator III

t	T	Q	COP_a	COP_{th}	η
0	0	0	0	0	0
1800	25.4	46.34	0.47	43.43	1.1
3600	20.7	67.42	0.72	25.34	2.8
5400	17.3	66.89	0.72	19.21	3.7
7200	13.2	68.55	0.73	15.05	4.9
9000	10.3	66.11	0.71	12.86	5.5
10800	7.4	63.99	0.69	11.28	6.1

Table 4 – The data from refrigerator IV

t	T	Q	COP_a	COP_{th}	η
0	0	0	0	0	0
1800	23.2	88.15	0.95	32.55	2.9
3600	19.3	80.65	0.87	22.48	3.8
5400	15.7	76.27	0.82	17.39	4.7
7200	13.6	67.29	0.72	15.30	4.7
9000	11.7	60.77	0.65	13.82	4.7
10800	9.7	56.85	0.61	12.52	4.8

Table 5 – The average values for the four Refrigerators

t	T	Q	COP_a	COP_{th}	η
0	0	0	0	0	0
1800	23.4	84.40	0.91	33.30	2.7
3600	18.5	88.16	0.95	21.12	4.5
5400	14.4	84.41	0.91	16.11	5.6
7200	11.1	78.78	0.85	13.40	6.3
9000	8.5	72.77	0.78	11.82	6.6
10800	6.0	68.47	0.73	10.61	6.9